

## AGGLOMERATION OF ALUMINA AND BINDER THEREFOR

### Field of the Invention

[0001] The present invention relates to a method for the agglomeration of particles of alumina, or particles containing a substantial portion of alumina, and a binder for use in such.

### Background of the Invention

[0002] In the Bayer process for the extraction of alumina from alumina containing ores, precipitated alumina tri-hydrate is filtered, dried and calcined. This yields high purity alumina with a narrow range of particle sizes. However, a by-product of the calcination process is extremely fine particles of alumina, with an average size of less than 30 µm. This by-product is caught in the gas cleaning devices, including multi-cyclones, electrostatic precipitators and/or bag-houses, attached to the calcination device. Such particles are commonly known as ESP dust. In addition to being difficult to handle, ESP dust is difficult to reintroduce into the process stream, not being readily redigested in the highly caustic solution of the digestion phase.

[0003] Accordingly, it is desirable to be able to agglomerate small particles of alumina, such as ESP dust, to form coarser particles. Ideally, these coarser particles are of a size range suitable for use in aluminium smelting.

[0004] In the ceramics industry, particles are agglomerated by spray drying using organic polymers as binders. However, the agglomerates formed by these methods are typically weakly bonded and they are readily degraded when handled or transported.

[0005] In Australian Patent 664328, there is provided a method for agglomerating

alumina particles with a binder comprising a polymer form of a hydroxy salt of aluminium. In a variant of the invention, activated alumina is used to reduce the quantities of the binding agent required. The activated alumina is believed to enhance binding by forming a film of pseudo boehmite that adheres to the particles of unactivated alumina powder. However, it is clearly stated that the activated alumina cannot be used alone to achieve beneficial agglomeration of the alumina particles.

[0006] However the cost of the binding agent, and that associated with the production of activated alumina, have prevented the widespread application of this method. It is one object of the present invention to provide a method for the agglomeration of particles of alumina, or particles comprising alumina, where the quantity of binder required is substantially reduced, and the need for activated alumina eliminated.

[0007] The preceding discussion of the background to the invention is intended to facilitate an understanding of the present invention. However, it should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was part of the common general knowledge in Australia as at the priority date of the application.

[0008] Throughout the specification, unless the context requires otherwise, the word “alumina” will be understood to encompass fully dehydrated alumina, fully hydrated alumina, partially hydrated alumina or a mixture of these forms.

[0009] Throughout the specification, unless the context requires otherwise, the term “alumina particles” will be understood to include particles of an alumina containing

material where the alumina content of said particles is at least about 30% by weight  $\text{Al}_2\text{O}_3$ .

[0010] Further, throughout the specification, unless the context requires otherwise, the word “comprise” or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

**[0011] Disclosure of the Invention**

[0012] In accordance with the present invention, there is provided a method for the agglomeration of alumina particles, the method comprising the steps of:

[0013] adding a quantity of pseudo-boehmite to the alumina particles; and

[0014] spray drying the mixture so formed to produce agglomerated granules.

[0015] Preferably, the pseudo-boehmite is added as an aqueous suspension.

[0016] Preferably, the aqueous suspension of pseudo-boehmite is formed at a temperature between about 15 and 100°C. Preferably still, the aqueous suspension of pseudo-boehmite is formed at a temperature above about 80°C. In a highly preferred form of the invention, the aqueous suspension of pseudo-boehmite is formed at a temperature above about 85°C.

[0017] Preferably, a quantity of acid is added to the aqueous suspension of pseudo-boehmite such that the pH of such is between about 2 and 6. Advantageously, a quantity of acid is added to the aqueous suspension of pseudo-boehmite such that the pH of such is approximately 3. Preferably, the acid is monoprotic. In a highly preferred form of the invention, the acid is acetic acid.

[0018] Preferably, before the step of adding a quantity of pseudo-boehmite to the alumina particles, the present invention comprises the step of comminuting the alumina particles to a  $D_{50}$  of less than 12  $\mu\text{m}$ . Preferably, the alumina particles are comminuted to a  $D_{50}$  of less than about 9  $\mu\text{m}$ . In a highly preferred form of the invention, the alumina particles are comminuted to a  $D_{50}$  of about 5  $\mu\text{m}$ .

[0019] The alumina particles may be comminuted by jet milling or by grinding means involving cermaic or metal grinding media including ball milling and bead milling.

[0020] In one form of the invention, a quantity of water is added to the alumina particles to form a slurry, the slurry then being subjected to grinding.

[0021] In an alternate form of the invention, the alumina particles are subjected to dry grinding before a quantity of water is added to form a slurry. Where the alumina particles are subjected to dry grinding before a quantity of water is added to form a slurry, the quantity of water may be provided by way of the aqueous suspension of pseudo-boehmite.

[0022] Preferably, the slurry is of as high a density as possible. Preferably still the slurry comprises at least 50% solids. Typically, the slurry comprises between about 40 and 60% solids.

[0023] The slurry may also contain a viscosity modifier. The viscosity modifier may be one or more of acetic acid, citric acid or a polyacrylate. Preferably, sufficient viscosity modifier is added such that the viscosity of the slurry is less than about 4 cp. In a preferred form of the invention, the viscosity modifier is acetic acid. In a highly

preferred form of the invention, sufficient acetic acid is introduced such that the concentration of the acetic acid in the slurry is between about 0.2 and 1.5% by weight of the alumina particles.

[0024] Preferably, before the quantity of pseudo-boehmite is added to the alumina particles, the method comprises the additional steps of:

[0025] neutralising, dewatering and washing the alumina particles.

[0026] In one form of the invention, dewatering is achieved by way of filtration.

In an alternate form of the invention, dewatering may be achieved by way of centrifugation. Preferably, carbon dioxide is used to neutralise the alumina particles.

[0027] The step of neutralising, dewatering and washing the alumina particles may be carried out before or after grinding the alumina particles. Conveniently, the step of neutralising, dewatering and washing the alumina particles is carried out before the step of grinding the alumina particles as a smaller filter may be used.

[0028] The method of the present invention may comprise the additional step of:

[0029] heating the agglomerated granules.

[0030] In one form of the invention, the agglomerated particles are dehydroxylated by heating to approximately 300°C. In an alternate form of the invention, the agglomerated granules are calcined above 500°C.

### **[0031] Best Mode(s) for Carrying Out the Invention**

[0032] The method of the present invention will subsequently be described, by way of example only, with reference to one embodiment thereof and several examples.

[0033] In the embodiment, a quantity of water is added to particulate alumina to

form a slurry of a density between about 40 and 60% solids. A viscosity modifier, in the form of acetic acid is added to the slurry such that the concentration of acetic acid in the slurry is between about 0.2 and 1.5% by weight of the alumina particles.

[0034] The slurry is then subjected to grinding such that the alumina particles are ground to a  $D_{50}$  of less than  $12\mu\text{m}$  and preferably about  $5\mu\text{m}$ .

[0035] A quantity of binding agent in the form of an aqueous suspension of pseudo boehmite is added to the slurry.

[0036] The aqueous suspension of pseudoboehmite is formed at a temperature above about  $80^\circ\text{C}$ , and preferably above about  $85^\circ\text{C}$ . A quantity of monoprotic acid, preferably acetic acid, is added to the aqueous suspension of pseudo boehmite such that the pH is about 3.0.

[0037] The mixture formed by the addition of the aqueous suspension of pseudo boehmite to the slurry is then spray dried to produce agglomerated granules.

[0038] The agglomerated granules may then be heated to in excess of approximately  $300^\circ\text{C}$  to effect dehydroxylation of such, or in excess of approximately above  $500^\circ\text{C}$  to effect calcination of such.

[0039] The present invention will now be described by way of several examples. However, it must be appreciated that the following description of those examples is not to limit the generality of the above description of the invention.

#### Example 1

[0040] One kilogram of alumina particles with a  $D_{50}$  of  $15.3\mu\text{m}$  was added to 1200 mL of water to form a slurry. Carbon dioxide gas was bubbled through the slurry until

the pH of such was about 6.5. Glacial acetic acid (5g) was added to the slurry, which was then heated to 85°C.

[0041] A quantity of a pseudo-boehmite suspension was added to the slurry. The pseudo-boehmite suspension was prepared by the dispersion of 50 g of a commercial pseudo-boehmite (either Catapal B (supplied by Vista Condea) or HiQ X (supplied by Alcoa World Chemicals)) in 200 g of 85°C water. After the mix returned to 85°C, 5 g of glacial acetic acid was added.

[0042] After mixing for several minutes the slurry to which the pseudo-boehmite suspension was added was then spray dried. Throughout the spray drying the off gas temperature was maintained at 180°C. Portions of the product were calcined at 500°C in a muffle furnace for one hour.

#### Example 2

[0043] One kilogram of alumina particles with a  $D_{50}$  of 15.3  $\mu\text{m}$  was added to 1200 mL of water to form a slurry. Carbon dioxide gas was bubbled through the slurry until the pH of such was about 6.5. The slurry was filtered and washed with a further 500 mL of water. The filter cake was then re-slurried in sufficient water to produce a slurry containing 50% solids. Glacial acetic acid (5g) was added to the final slurry, which was then heated to 85°C.

[0044] A quantity of a pseudo-boehmite suspension was added to the slurry. The pseudo-boehmite suspension was prepared by the dispersion 50 g of a commercial pseudo-boehmite (either Catapal B (supplied by Vista Condea) or HiQ X (supplied by

Alcoa World Chemicals)) in 200 g of 85°C water. After the mix returned to 85°C, 5 g of glacial acetic acid was added.

[0045] After mixing for several minutes the slurry to which the pseudo-boehmite suspension was added was then spray dried. Throughout the spray drying the off gas temperature was maintained at 180°C. Portions of the product were calcined at 500°C in a muffle furnace for one hour.

### Example 3

[0046] One kilogram of alumina particles with a D<sub>50</sub> of 15.3 µm was added to 1200 mL of water to form a slurry. Carbon dioxide gas was bubbled through the slurry until the pH of such was about 6.5. The slurry was filtered and washed with a further 500 mL of water. The filter cake was then re-slurried in sufficient water to produce a slurry containing 50% solids. Glacial acetic acid (5g) was added to the final slurry, which was then heated to 85°C.

[0047] A quantity of a pseudo-boehmite suspension was added to the slurry. The pseudo-boehmite suspension was prepared by the dispersion 20 gm of a commercial pseudo-boehmite (either Catapal B (supplied by Vista Condea) or HiQ X (supplied by Alcoa World Chemicals)) in 200 g of 85°C water. After the mix returned to 85°C, 5 g of glacial acetic acid was added.

[0048] After mixing for several minutes the slurry to which the pseudo-boehmite suspension was added was then spray dried. Throughout the spray drying the off gas temperature was maintained at 180°C. Portions of the product were calcined at 500°C in a muffle furnace for one hour.

#### Example 4

[0049] Alumina particles with a  $D_{50}$  of 15.3  $\mu\text{m}$  were slurried in water. Carbon dioxide gas was bubbled through the slurry until the pH of such was about 6.5. The slurry was filtered and washed with a further 500 mL of water, then dried. The powder was then dry ground in a Jet Mill. One kilogram of the ground alumina particles was added to 800 mL of water to form a slurry. Glacial acetic acid (5g) was added to the final slurry, which was then heated to 85°C.

[0050] A quantity of a pseudo-boehmite suspension was added to the slurry. The pseudo-boehmite suspension was prepared by the dispersion 10 gm of a commercial pseudo-boehmite (either Catapal B (supplied by Vista Condea) or HiQ X (supplied by Alcoa World Chemicals)) in 200 g of 85°C water. After the mix returned to 85°C 5 g of glacial acetic acid was added.

[0051] After mixing for several minutes the slurry to which the pseudo-boehmite suspension was added was then spray dried. Throughout the spray drying the off gas temperature was maintained at 180°C. Portions of the product were calcined at 500°C in a muffle furnace for one hour.

#### Example 5

[0052] Alumina particles with a  $D_{50}$  of 15.3  $\mu\text{m}$  were slurried in water. Carbon dioxide gas was bubbled through the slurry until the pH of such was about 6.5. The slurry was filtered and washed with a further 500 mL of water, then dried. The powder was then dry ground in a Jet Mill. One kilogram of the ground alumina particles was

added to 620 mL of water to form a slurry. Glacial acetic acid (4.4g) was added to the final slurry, which was then heated to 85°C.

[0053] A quantity of a pseudo-boehmite suspension was added to the slurry. The pseudo-boehmite suspension was prepared by the dispersion 10 gm of a commercial pseudo-boehmite (either Catapal B (supplied by Vista Condea) or HiQ X (supplied by Alcoa World Chemicals)) in 200 g of 85°C water. After the mix returned to 85°C, 0.7 g of glacial acetic acid was added.

[0054] After mixing for several minutes the slurry to which the pseudo-boehmite suspension was added was then spray dried. Throughout the spray drying the off gas temperature was maintained at 180°C. Portions of the product were calcined at 500°C in a muffle furnace for one hour.

#### Example 6

[0055] Alumina particles with a  $D_{50}$  of 15.3  $\mu\text{m}$  were slurried in water. Carbon dioxide gas was bubbled through the slurry until the pH of such was about 6.5. The slurry was filtered and washed with a further 500 mL of water, then dried. The powder was then dry ground in a Jet Mill. One kilogram of the ground alumina particles was added to 800 mL of water to form a slurry. Glacial acetic acid (5g) was added to the final slurry, which was then heated to 85°C.

[0056] A quantity of a pseudo-boehmite suspension was added to the slurry. The pseudo-boehmite suspension was prepared by the dispersion 20 gm of a commercial pseudo-boehmite (either Catapal B (supplied by Vista Condea) or HiQ X (supplied by

Alcoa World Chemicals)) in 200 g of 85°C water. After the mix returned to 85°C, 5 g of glacial acetic acid was added.

[0057] After mixing for several minutes the slurry to which the pseudo-boehmite suspension was added was then spray dried. Throughout the spray drying the off gas temperature was maintained at 180°C. Portions of the product were calcined at 500°C in a muffle furnace for one hour.

#### Example 7

[0058] One kilogram of alumina particles with a D<sub>50</sub> of 15.3 µm was added to 800 mL of water to form a slurry. Carbon dioxide gas was bubbled through the slurry until the pH of such was about 6.5. Glacial acetic acid (5g) was added to the slurry, which was then heated to 85°C. This slurry was ground for 30 minutes in a laboratory jar mill.

[0059] A quantity of a pseudo-boehmite suspension was added to the slurry. The pseudo-boehmite suspension was prepared by the dispersion 20 gm of a commercial pseudo-boehmite (either Catapal B (supplied by Vista Condea) or HiQ X (supplied by Alcoa World Chemicals)) in 200 g of 85°C water. After the mix returned to 85°C, 5 g of glacial acetic acid was added.

[0060] After mixing for several minutes the slurry to which the pseudo-boehmite suspension was added were then spray dried. Throughout the spray drying the off gas temperature was maintained at 180°C. Portions of the product were calcined at 500°C in a muffle furnace for one hour.

#### Example 8

One kilogram of alumina particles with a D<sub>50</sub> of 15.3 µm was added to 1200 mL of water

to form a slurry. Carbon dioxide gas was bubbled through the slurry until the pH of such was about 6.5. The slurry was filtered and deliquored. The filter cake was then reslurried in sufficient water to produce a slurry containing 50% solids. Glacial acetic acid (5g) was added to the final slurry, which was then heated to 85°C. This slurry was ground for 30 minutes in a laboratory jar mill.

[0061] A quantity of a pseudo-boehmite suspension was added to the slurry. The pseudo-boehmite suspension was prepared by the dispersion 20 gm of a commercial pseudo-boehmite (either Catapal B (supplied by Vista Condea) or HiQ X (supplied by Alcoa World Chemicals)) in 200 g of 85°C water. After the mix returned to 85°C 5 g of glacial acetic acid was added.

[0062] After mixing for several minutes the slurry to which the pseudo-boehmite suspension was added was then spray dried. Throughout the spray drying the off gas temperature was maintained at 180°C. Portions of the product were calcined at 500°C in a muffle furnace for one hour.

#### Example 9

[0063] One kilogram of alumina particles with a  $D_{50}$  of 15.3  $\mu\text{m}$  was added to 1200 mL of water to form a slurry. Carbon dioxide gas was bubbled through the slurry until the pH of such was about 6.5. The slurry was filtered and washed with a further 500 mL of water. The filter cake was then reslurried in sufficient water to produce a slurry containing 50% solids. Glacial acetic acid (5g) was added to the slurry, which was then heated to 85°C. This slurry was ground for 30 minutes in a laboratory jar mill.

[0064] A quantity of a pseudo-boehmite suspension was added to the slurry. The pseudo-boehmite suspension was prepared by the dispersion 8 gm of a commercial pseudo-boehmite (either Catapal B (supplied by Vista Condea) or HiQ X (supplied by Alcoa World Chemicals)) in 200 g of 85°C water. After the mix returned to 85°C 5 g of glacial acetic acid was added.

[0065] After mixing for several minutes the slurry to which the pseudo-boehmite suspension was added was then spray dried. Throughout the spray drying the off gas temperature was maintained at 180°C. Portions of the product were calcined at 500°C in a muffle furnace for one hour.

#### Example 10

[0066] Alumina particles with a  $D_{50}$  of 15.3  $\mu\text{m}$  were slurried in water. Carbon dioxide gas was bubbled through the slurry until the pH of such was about 6.5. The slurry was filtered and washed with a further 500 mL of water, then dried. The powder was then dry ground in a Jet Mill. One kilogram of the ground alumina particles was added to 800 mL of water to form a slurry. Glacial acetic acid (5g) was added to the final slurry.

[0067] A quantity of a pseudo-boehmite suspension was added to the slurry. The pseudo-boehmite suspension was prepared by the dispersion 40 gm of a commercial pseudo-boehmite (either Catapal B (supplied by Vista Condea) or HiQ X (supplied by Alcoa World Chemicals)) in 200 g of water at room temperature. 5 g of glacial acetic acid was added to this mix.

[0068] After mixing for several minutes the slurry to which the pseudo-boehmite suspension was added was then spray dried. Throughout the spray drying the off gas temperature was maintained at 180°C. Portions of the product were calcined at 500°C in a muffle furnace for one hour.

#### Example 11

[0069] Alumina particles with a  $D_{50}$  of 15.3  $\mu\text{m}$  were slurried in water. Carbon dioxide gas was bubbled through the slurry until the pH of such was about 6.5. The slurry was filtered and washed with a further 500 mL of water, then dried. The powder was then dry ground in a Jet Mill. One kilogram of the ground alumina particles was added to 800 mL of water to form a slurry. Glacial acetic acid (5g) was added to the final slurry.

[0070] A quantity of a pseudo-boehmite suspension was added to the slurry. The pseudo-boehmite suspension was prepared by the dispersion 20 gm of a commercial pseudo-boehmite (either Catapal B (supplied by Vista Condea) or HiQ X (supplied by Alcoa World Chemicals)) in 200 g of water. 5 g of glacial acetic acid was added to the mix.

[0071] After mixing for several minutes the slurry to which the pseudo-boehmite suspension was added was then spray dried. Throughout the spray drying the off gas temperature was maintained at 180°C. Portions of the product were calcined at 500°C in a muffle furnace for one hour.

[0072] A summary of the test conditions for Examples 1 to 11 appears in Table 1, below.

Table 1

Example	Dust D50 ( $\mu\text{m}$ )	Filtered	Washed	How Milled	SD Feed D50, ( $\mu\text{m}$ )	Binder (%)	Peptise T, ( $^{\circ}\text{C}$ )
1	15.3	No	No	No	15.3	5	85
2	15.3	Yes	Yes	No	15.3	5	85
3	15.3	Yes	Yes	No	15.3	2	85
4	15.3	Yes	Yes	Dry	4.6	1.0	85
5	15.3	yes	yes	Dry	4.6	1.0	85
6	15.3	Yes	Yes	Dry	4.6	2.0	85
7	15.3	No	No	Wet	5.0	2.0	85
8	15.3	Yes	No	Wet	5.3	2.0	85
9	15.3	Yes	Yes	Wet	5.4	0.8	85
10	15.3	Yes	Yes	Dry	4.6	4.0	20
11	15.3	Yes	Yes	Dry	4.6	2.0	20

TYPICAL PREPARATION OF MICRO AGGLOMERATES

[0073] Product samples were analysed for soda content so as to distinguish the effect of washing the feed dust, as it was suspected that soda content may adversely affect boehmitic gel formation. The results of the soda content analyses of the agglomerates appear in Table 2, below

Table 2

Example	1	2, 3	4, 5, 6, 10, 11	7	8	9
% soda	0.78	0.33	0.27	0.77	0.30	0.33

[0074] Samples of the micro agglomerates were analysed for particle size distribution. The results of the particle size distribution analysis are given in Table 3, below. For comparative purposes the size analysis of regular smelting grade alumina (SGA) is also included.

Table 3

Cumulative percent passing size	1000 $\mu\text{m}$	300 $\mu\text{m}$	212 $\mu\text{m}$	150 $\mu\text{m}$	106 $\mu\text{m}$	75 $\mu\text{m}$	53 $\mu\text{m}$
Example 1	100	79.8	54.4	35.5	21.4	16.3	13.7
Example 2	100	84.2	61.2	36.7	15.5	5.7	2.1
Example 3	100	82.7	58.3	34.0	13.6	4.6	1.4
Example 4	100	85.5	58.3	32.3	12.9	3.9	1.0
Example 5	100	87.4	69.5	47.7	24.0	9.0	2.6
Example 6	100	83.0	51.8	27.8	10.9	3.9	1.4
Example 7	100	63.1	33.8	16.7	6.8	4.2	3.5
Example 8	100	77.7	49.2	27.7	10.6	2.4	0.3
Example 9	100	91.2	72.2	48.1	24.6	9.5	2.8
Example 10	100	89.9	62.4	37.6	16.6	5.7	1.7
Example 11	100	92.3	67.7	38.0	16.1	5.9	1.9
SGA1	100	99.9	99.7	95.3	70.1	34.8	13.8
SGA2	100	100	100	94.4	42.7	15.0	4.8

[0075] In all cases the micro agglomerates formed are of a size slightly coarser than smelting grade alumina, but which is acceptable for the end use.

[0076] The micro agglomerates were also tested for strength using an attrition test wherein 25 g of micro agglomerate was placed on the top screen in a stack on a RoTap shaker, and the shaker was activated for 5 minutes. A separate sample was placed on the shaker for 20 minutes. The difference in particle size distribution was used as a comparative breakage test for the samples. The results were compared to a sample of smelting grade alumina. The results of this testing are given in Tables 4 and 5. Table 4, below, shows the results of the attrition testing conducted on the discharge from the spray dryer.

Table 4

Screen size	300 μm	212 μm	150 μm	106 μm	75 μm	53 μm	-53 μm
(Change in percent of material retained on screen between 5 and 20 minute shaking)							
Example 1	-19.7	-25.2	-17.8	-0.6	1.2	0.6	61.4
Example 2	-2.9	-0.7	1.1	0.9	0.3	0.1	1.2
Example 3	-16.9	-16.4	9.2	4.6	1.9	1.0	16.6
Example 4	-1.7	-1.2	0.8	1.2	0.4	0.2	0.4
Example 5	-2.2	-.1	0.5	0.7	0.1	0.2	0.9
Example 6	-2.3	0.3	0.8	0.4	0.1	0.3	0.5
Example 7	-36.0	-28.7	-14.0	11.4	-0.1	1.3	66.1
Example 8	-7.5	1.4	2.2	1.1	0.6	0.4	1.7
Example 9	-1.4	-0.9	0.5	0.6	0.2	-0.1	1.2
Example 10	-0.6	-0.4	0.2	0.1	0.1	0.2	0.4
Example 11	-5.3	0.9	1.6	0.8	0.2	0.1	1.7
SGA1	-0.1	-0.1	-0.5	-0.5	-0.4	0	1.7
SGA 2	0	0	-0.5	-1.1	1.0	0	0.7

[0077] Of particular interest is the increase in the finest portion of the measured particle size distribution (53 μm) and we can see that the micro agglomerates produced in examples 2, 4, 5, 6, 8 and 9 are of comparable attrition resistance to smelting grade alumina. Examples 10 and 11 demonstrated acceptable attrition resistance.

[0078] On the basis of these results it was determined that the product of examples 1, 3 and 7 had unsatisfactory attrition resistance and no further testing was conducted. The attrition test results of the paired Examples 1 and 2 and also 7 and 8 suggest that the soluble soda levels of the alumina dust must be reduced before this pseudo-boehmite binding system can be effectively applied. Apparently the presence of soluble salts interferes with the peptisation of the pseudo-boehmite.

[0079] A comparison of examples 2 and 3 with examples 6 and 8 show that to produce attrition resistant product a higher binder level (5% for example 2, 2% in examples 3, and 6) is required with coarser dusts.

[0080] Table 5, below, shows the results of the attrition testing for micro agglomerates which have been calcined to 500°C.

Table 5

Screen size	300 μm	212 μm	150 μm	106 μm	75 μm	53 μm	-53 μm
(Change in percent of material retained on screen between 5 and 20 minute shaking)							
Example 2	-6.6	1.0	2.1	1.2	0.6	0.3	1.4
Example 4	-1.8	-1.3	0.9	1.2	0.4	0.2	0.4
Example 5	-9.4	-4.1	3.3	4.1	1.0	1.0	4.0
Example 6	-10.9	3.1	3.6	1.4	0.8	0.3	1.7
Example 8	-15.8	4.8	4.6	2.1	0.9	0.8	2.7
Example 9	-5.8	-1.6	2.5	2.0	1.0	0.4	1.5
Example 10	-2.0	-0.6	0.8	0.9	0.3	0.1	0.5
Example 11	-5.9	-19.4	-9.8	11.5	3.3	2.5	17.8
SGA1	-0.1	-0.1	-0.5	-0.5	-0.4	0	1.7
SGA 2	0	0	-0.5	-1.1	1.0	0	0.7

[0081] Calcination to 500°C dehydroxylates any gibbsite which may be present in the dust, and the added pseudo-boehmite. Attrition resistance remains generally acceptable. Whilst demonstrating acceptable attrition resistance down to the 2% binder level before calcination, Examples 10 and 11 showed unsatisfactory attrition resistance below 4% binder concentration after calcination. In Examples 10 and 11 the alumina particles were peptised at 20 °C.

[0082] Another set of experiments demonstrated the effect of comminuting

alumina particles before they are combined with a binder. ESP dust was collected and milled in a Hosokawa Alpine Jet Mill. The analysis of the treated ESP dust appears in Table 6 below.

Table 6

	% Na <sub>2</sub> O	D <sub>10</sub>	D <sub>50</sub>	D <sub>90</sub>	% Loss to 105°C	% Loss 105-300°C	% Loss 300-950°C	Total % loss
As Collected	0.61	3.7	13.9	35.6				
As Treated	0.27	2.0	3.0	5.7	1.17	16.04	4.05	21.26

[0083] A slurry of water, poly aluminum hydroxy chloride (PAC) binder and the treated ESP dust was prepared to a solids density of approximately 50%. The slurry was then spray dried to form micro agglomerates under the conditions set out in Table 7 below.

Table 7

% PAC	pH	Spray Dryer Exhaust Temparture, °C
10	3.8	138.5
7	4.2	130
5	5.1	130
4	5.5	145
3	5.3	145
2	6.2	145

[0084] Six runs were conducted at different PAC addition levels. Agglomeration was noted in all cases. Particle size distribution analyses were conducted on the micro agglomerates. The particle size distribution (by screening) of the product is shown in Table 8 below.

Table 8

Cumulative % passing size	1000 µm	500 µm	300 µm	212 µm	106 µm	45 µm
10% PAC	100	95.3	90.2	80.5	33.5	2.8
7 % PAC	100	95.3	89.0	80.1	31.8	2.4
5 % PAC	100	96.5	89.0	72.4	24.6	1.6
4 % PAC	100	95.8	84.0	62.3	20.2	1.1
3 % PAC	100	89.5	78.4	59.1	19.3	0.9
2 % PAC	100	89.3	71.9	75.7	5.2	0.2

[0085] As can be seen, the product micro agglomerates are similar to the desired smelting grade alumina sizing.

[0086] The micro agglomerates produced were tested for strength using an attrition test wherein 10 g of micro agglomerate was placed on the top screen in a stack on a Rop Tap, shaker and the shaker was activated for 5 minutes. A separate sample was placed on the shaker for 20 minutes. The difference in particle size distribution was used as a comparative breakage test for the samples. The results of the attrition test conducted on agglomerates formed with 7% PAC appear in Table 9 below.

Table 9

Time	Not Calcined			600°C			900°		
	5 min.	20 min.	delta	5 min.	20 min.	delta	5 min.	20 min.	delta
Size (mic)	% Retained								
+300	6.47	4.44	-2.03	4.44	2.11	-2.33	3.91	1.58	-2.33
-300/+212	9.88	10.55	0.67	9.11	9.03	-0.08	11.04	10.02	-1.02
-212/+150	23.42	23.92	0.49	23.36	23.44	0.07	26.15	26.50	0.34
-150/+106	26.75	27.01	0.27	29.00	28.30	-0.70	29.27	30.15	0.88
-106/+75	16.64	16.79	0.15	17.39	18.29	0.90	16.41	17.26	0.84
-75/+53	9.29	8.94	-0.36	9.13	9.52	0.39	7.81	7.94	0.13
-53	7.54	8.35	0.81	7.57	9.31	1.74	5.40	6.56	1.16

[0087] The results of the attrition tests conducted on agglomerates formed with 5% PAC appear in Table 10 below.

Table 10

Time	Not Calcined			600°C			900°C		
	5 min.	20 min.	delta	5 min.	20 min.	delta	5 min.	20 min.	delta
Size (mic)	% Retained								
+300	7.67	4.99	-2.69	2.02	0.19	-1.83	1.65	0.18	-1.47
-300/+212	15.74	16.71	0.97	14.56	10.32	-4.24	15.13	4.50	-10.63
-212/+150	25.92	26.65	0.73	26.35	29.14	2.80	26.92	33.93	7.01
-150/+106	24.78	25.14	0.36	27.03	28.33	1.30	26.86	29.13	2.27
-106/+75	13.96	13.93	-0.03	15.55	16.02	0.47	15.54	16.24	0.70
-75/+53	7.18	7.08	-0.10	8.44	8.48	0.04	8.03	8.42	0.39
-53	4.74	5.50	0.77	6.05	7.51	1.47	5.89	7.62	1.73

[0088] The results of the attrition tests conducted on agglomerates formed with 3% PAC appear in Table 11 below.

Table 11

		Not Calcined		
Time		5 min.	20 min.	delta
Size (mic)		% Retained		
+300		19.34	8.87	-10.47
-300/+212		19.77	21.66	1.90
-212/+150		22.16	27.33	5.17
-150/+106		21.43	23.57	2.14
-106/+75		9.46	9.60	0.14
-75/+53		5.46	5.61	0.14
-53		2.38	3.36	0.98

[0089] The results of the attrition tests conducted on agglomerates formed with 10% PAC appear in Table 12 below.

Table 12

Time	Not Calcined			600°C			900°C		
	5 min.	20 min.	Delta	5 min.	20 min.	delta	5 min.	20 min.	delta
Size (mic)	% Retained								
+300	6.05	4.82	-1.23	4.34	2.37	-2.00	3.38	1.36	-2.02
-300/+212	11.40	8.78	-2.62	7.81	7.53	-0.29	7.65	7.24	-0.41
-212/+150	19.92	20.86	0.94	19.14	19.39	0.25	18.62	18.98	0.36
-150/+106	26.23	27.20	0.97	28.06	28.11	0.04	27.24	27.79	0.56
-106/+75	17.39	18.05	0.66	19.31	19.49	0.18	19.25	19.69	0.43
-75/+53	10.30	10.21	-0.09	10.88	11.11	0.23	11.84	11.69	-0.15
-53	8.71	10.07	1.36	10.46	12.01	1.55	12.02	13.25	1.23

[0090] The results of the attrition tests conducted on agglomerates formed with 4% PAC appear in Table 13 below.

Table 13

Time	Not Calcined			600°C			900°C		
	5 min.	20 min.	delta	5 min.	20 min.	delta	5 min.	20 min.	Delta
Size (mic)	% Retained								
+300	13.02	10.72	-2.30	5.25	0.20	-5.05	2.938	0.24	-2.70
-300/+212	22.13	23.06	0.93	24.28	14.42	-9.86	27.37	11.24	-13.13
-212/+150	23.47	23.92	0.45	24.92	33.95	9.02	26.18	36.16	9.98
-150/+106	21.91	22.18	0.27	23.00	25.98	2.98	23.92	26.85	2.93
-106/+75	10.53	10.25	-0.28	11.70	11.10	-0.60	11.34	11.06	-0.28
-75/+53	5.73	5.89	0.15	5.69	6.16	0.47	5.91	5.80	-0.12
-53	3.20	3.98	0.78	5.16	8.19	3.03	5.33	8.66	3.33

[0091] The results of the attrition tests conducted on agglomerates formed with 2% PAC appear in Table 14 below.

Table 14

		Not Calcined		
Time		5 min.	20 min.	delta
Size (microns)		% Retained		
+300		19.65	11.52	-8.13
-300/+212		30.03	18.13	-11.90
-212/+150		24.81	29.85	5.04
-150/+106		14.64	23.52	8.87
-106/+75		4.81	4.80	-0.01
-75/+53		3.72	7.01	3.29
-53		2.32	5.17	2.85

[0092] The results were compared to micro agglomerates formed using unground ESP and 10% PAC. The results of the attrition tests conducted on agglomaerates formed with 10% PAC and unground ESP dust appear in Table 15 below.

Table 15

Time	Not Calcined			600°C			900°C		
	5 min.	20 min.	delta	5 min.	20 min.	delta	5 min.	20 min.	delta
Size (mic)	% Retained								
+300	4.12	3.26	-0.86	0.82	0.49	-0.33	0.79	0.29	-0.50
-300/+212	6.17	6.01	-0.16	6.16	5.07	-1.09	5.84	4.43	-1.41
-212/+150	15.64	15.84	0.19	16.11	15.83	-0.27	15.84	15.62	-0.23
-150/+106	25.57	25.45	-0.12	28.62	28.90	0.28	29.15	29.64	0.49
-106/+75	20.44	20.51	0.068	24.27	24.19	-0.08	23.99	24.27	0.28
-75/+53	13.61	13.13	-0.48	15.91	15.34	-0.57	15.90	15.22	-0.68
-53	14.43	15.8	1.37	8.10	10.17	2.07	8.49	10.54	2.05

[0093] The results were compared to the attrition behavior of a typical smelting grade alumina. Results of the attrition test conducted on a typical smelting grade alumina appear in Table 16 below.

Table 16

Attrition Time, (min)	5 min.	20 min.	Delta
Size Range, microns	%Retained		
+300	0.15	0.02	-0.13
-300/+212	0.13	0.00	-0.13
-212/+150	4.48	3.94	-0.54
-150/+106	25.15	24.67	-0.48
-106/+75	35.33	34.92	-0.41
-75/+53	20.96	20.97	0.00
-53	13.80	15.48	1.68
	100.00	100.00	

[0094] The results demonstrate that before calcination, the products of mixes containing greater than 4% PAC binder have comparable resistance to the product of the unground ESP with 10% PAC binder. After heating to 600°C, there is more breakage of coarse particles at the 5% PAC level, and considerably more at the 4% PAC level. Most of this material goes into the 106 to 212 µm range and there is only a small increase in the smallest fraction measured. After heating to 900°C, there is much more breakage from the coarse fractions of the 4% PAC and 5% PAC samples than the product of the unground ESP. Again, most of this material goes into the 106 to 212 µm range and there is only a small increase in the smallest fraction measured.